PRACE
INSTYTUTU GEOGRAFICZNEGO
UNIWERSYTETU JAGIELLOŃSKIEGO
WYDAWANE PRZEZ
LUDOMIRA SAWICKIEGO

TRAVAUX
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LUDOMIR SAWICKI

ZESZYT 3 FASCICULE

LUDOMIR SAWICKI

Z GEOMORFOLOGJI CENTRALNEGO CEYLONU

ON THE GEOMORPHOLOGY OF CENTRAL CEYLON

KRAKÓW 1925
NAKŁADEM KSIĘGARNI GEOGRAFICZNEJ „ORBIS"
41, UL. BARSKA 41.

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Czcionkami drukarni „Orbis" w Krakowie.

Kiedy w czerwcu 1923, wracając z podróży naukowej do Sjamu, przymusowo zatrzymać się musiałem na krótki czas w Colombo na Ceylonie, skorzystałem z okazji, by przestudjować dokładniej zbiory Instytutu Kartograficznego. Wśród nich uderzyła mnie rzeźba całej centralnej i południowej części tej wyspy, wykonana w wielkiej podziałce (1:63.000) i w tylko podwójnem przewyższeniu. Rzeźba ta oddaje krajobraz wyspy z taką dokładnością i wiernością, że w wysokim stopniu ułatwić może jej studjum. Cóż dopiero, kiedy na niej występowały już przy pierwszem dokładniejszem obejrzeniu tak wielorakie i ciekawe zagadnienia morfogenetyczne, że dziwić się należało, iż nie wzbudziły one dotąd zainteresowania i nie zachęciły do szczegółowych badań żadnego z rzeszy licznych uczonych całego świata, którzy przewijają się przez Colombo — jedną z najbardziej ożywionych stacyj ruchu światowego — i zwiedzają w najrozmaitszych celach Ceylon, tą perłę wśród ziem podrównikowych. Dlatego też, postanowiłem ogłosić wyniki swych studjów; — choć nie mogłem wniosków wyciągniętych na podstawie bardzo dokładnego studjum rzeźby w Survey Departament skontrolować i uzupełnić w przyrodzie — mając na oku ogólne ubóstwo literatury morfologicznej, odnoszącej się do Ceylonu, i prawdopodobieństwo, że nie będzie mi już danem powrócić dla dokładniejszych badań do tego „raju ludzkości“, uważałem je bowiem za dostatecznie interesujące, by mogły innych szczęśliwszych zachęcić do ich skontrolowania i dalszego rozwinięcia. Niech będą jednym z dowodów więcej, że Polakom nie zabrakło nigdy na dobrej woli około rozbudowy gmachu ogólnej wiedzy ludzkiej, a tylko nieraz twarde warunki rzeczywistości uniemożliwiły im pracę, do której ich parła gorąca miłość poznania.

Czytelników polskich, którzyby bliżej zapoznać się chcieli z warunkami morfogenetycznemi centralnego Ceylonu, odsyłam do

szczegółowych wywodów tekstu obcojęzycznego. Pragnę tu tylko zebrać myśli przewodnie tej analizy, z których wynika, że Ceylon może stanowić zarówno jako wyjątkowo przejrzysty i skomplikowany teren, jak i przez swe położenie u splotu elementów morfogenetycznych azjatyckich i afrykańskich bardzo ważny i ciekawy przedmiot badań.

Dzisiejszy swój bardzo urozmaicony krajobraz Ceylon centralny uzyskał skutkiem podwójnego młodocianego dźwignięcia epeirogenetycznego, po raz pierwszy obecnie wykazanego, z którym skojarzyły się liczne procesy klinowego ustawienia dawnych prawierówni, fałdowań typu jurajskiego, wywołanych naporem dźwigających się mas, wgięć i załamań się kotlin różnego kształtu i zjawisk torsji i dylatacji skorupy ziemskiej, do których stara się dopasować przetrwały system odwodnienia, czasem ze skutkiem, czasami jednak i bezskutecznie. Pierwszy z tych ruchów epeirogenetycznych wydźwignął starą prawierównię centralnego Ceylonu — poziom Horton Plains, jak go nazywamy — o 2.000 stóp i ustawił ją przytem skośnie, nachylając ją znacznie w kierunku północnym. Wywołane temsamem odmłodnienie dolin zniszczyło przeważną część tej prawierówni starej, a utworzyło w jej miejsce drugą, niższą prawierównię, znakomicie zachowaną zarówno na wschód, jak i na zachód od wyżyny centralnej Horton Plains, w poziomie, który nazwaliśmy podług miast Bandarawela i Hatton. Te dwa typy różnowiekowych prawierówni graniczą ze sobą dość ostremi progami krajobrazowemi, przez które rzeki przebiegają urocznemi wodospadami. Morfologicznie ważniejszem było drugie dźwignięcie o charakterze epeirogenetycznym, które podniosło poziom Bandarawela-Hatton o dalsze 4.000 stóp, nachyliło przytem centralny Ceylon zarówno w kierunku północnym, jak i wschodnim i umożliwiło w ten sposób istniejącemu już, starszemu od rzeźby systemowi odwodnienia zachowanie, przynajmiej częściowo swych dawnych kierunków odpływu.

Ten drugi system dźwignięć epeirogenetycznych był — jak już zaznaczyliśmy — o wiele silniejszy od pierwszego: on wytworzył na zachodzie przez boczne parcie cały potężny i przepiękny system fałdowych gór, na południu objawy dylatacji skorupy ziemskiej, na północy wreszcie bardzo charakterystyczną wirgację. Skutkiem tych procesów podkopaną została pierwotna równowaga między poszczególnemi systemami odwodnienia, co spowodowało zażartą walkę o działy wodne, która toczyła się i dalej się toczy

w różnych miejscach centralnego Ceylonu. Potężne odmłodnienie, które dźwignięciu towarzyszyło, wytworzyło olbrzymie masy materjału akumulacyjnego; zasypane zostały niemi zarówno całkowicie, jak i częściowo peryferyczne górotwory, wreszcie w większej odległości urosły z nich przy czynnem współdziałaniu fal morskich rozległe niziny napływowe, które dziś jak wieniec otaczają z wszystkich stron centralny masyw Ceylonu.

Wiek wszystkich tych procesów nie da się na razie ustalić: dopiero przyszłe drobiazgowe badania będą musiały go wyświetlić podobnie jak znaczenie petrograficznej predyspozycji i starszej tektonicznej struktury. W odróżnieniu od niej procesy, które powyżej wykazaliśmy, są bardzo młodociane: świadczą o tem nie tylko sama analiza morfogenetyczna, ale i zjawiska wulkanizmu, gorące źródła, młodociane przesunięcia linji brzegowej na Ceylonie, niedostatecznie dotąd zbadane. Szczególnego jednak znaczenia nabierają wszystkie te okoliczności dlatego, że niewątpliwie na Ceylonie szukać należy klucza do związania skibowych afrykańskich elementów morfologicznych z fałdowemi południowo- i wschodnio-azjatyckiemi.

Kraków, w grudniu 1923 r.

ON THE MORPHOLOGY OF CENTRAL CEYLON

Returning fron a scientific journey to Siam I had the opportunity during my short stay at Colombo, to study the great relief of the central part of Ceylon, made first in cartoon, after the survey under the direction of W. C. S. Ingles, Surveyer General of Ceylon, and afterwards executed in plaster under the guidance of Mr. W. S. Maddams the cartographer[1]). The relief represents the central mountains of the inner part of Ceylon on a scale of 1:63.000, twice enlarged in height. In accordance with the progress of the Survey it comprises the neighbouring lowlands. In the course of this year Western, Southern and Eastern coasts are expect to be finished and during the next four or five years the lowlands of the Northern part of the island are to be surveyed.

The part of the relief already finished is of the greatest interest to morphologists, the more so that the existing scientific literature about the morphological problems of Ceylon for the most part does not yet solve them. In reality the study of them in the field encounters certain obstacles. They are the consequences of the conditions of communication as well as of vegetation. Not quite certain whether I should ever have an opportunity of returning to this classical country for the purpose of morphological exploration I have the courage to publish some results of my relief-study, although I did not have the possibility to explore them in the field. They seem to me not to be devoid of some general interest. My aim will be obtained if only this short study encourages the local explorers to develop the hypothesis presented here.

The oblique profile of the island, drawn along parallel 6° 48' N. lat. gives us the best information about the morphological

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[1]) My thanks are due to both these gentlemen, who have so well deserved of the cartography of Ceylon, for their kindness to me during my studies in the treasures of the Survey Departament.

structure of Central Ceylon. It begins on the Western Coast between Mount Lavinia and Angulana as an alluvial-plain (flood-plain) (I); it is crossed by rivers which meander and at the same time accumulate largely. On their way the rivers leave many cut-offs (ox-bow-lakes); as we come near the seashore there are lakes formed by the sea: one of these for instance is the Bolgoda Lake which is crossed by the profile. Some of them have already become marshy swamps.

This flood-plain reaches across the Mukuladuwa near Kesbewa and Mattegola the valley of Mundun-Ela, on whose Western slope there rises the hill of Magauunana (164').

It forms the outward border of an upland (II) from 100 to 300' heigh, gently undulating, with many terraces. Here and there it is crossed by large plains, e. g. near Pitipana and Kotingangada near Padukka. The Mirigyagallakanda (626') is the highest point of this upland. The heights of that plateau, which seven miles in breadth with numerous rocks (as Madagoda on the northern side of Horana) betray the preponderance of the NW-direction of the strata, but they show also in some particulars a very complicated topography.

On the East of the Katugalgama we see a prominent highland (III). It is formed of many ranges from 1200' to 1700' heigh. They all have a decided NNW-direction. Between them there are characteristic valleys, one parallel to the other in a longitudinal direction. In our profile thie type of landscape contains the ridges of Moraya Kanda (1174'), Handagala Kanda (1216') and Dungala (1721'). The longitudinal valleys have the baselevel only 100' heigh (Karandana Ela), so that the relative difference of the elevation amounts nearly from 1000' to 1500'.

This type of landscape has an extraordinary analogy to the Jura of France and Switzerland. In its whole breadth nearly from 10 to 15 miles it shows all the stages of development of a subsequent valley. This valley coincides with the former structural and petrographical conditions. The crossvalleys cut through some ranges or even the whole mountain-group. They are the effect of erosion and have a decidedly straight direction. There are a great variety of deep ravines. They carve the ranges forming narrow valleys where they correspond to the synclines, or enlarging in plains upon the part of the anticlines. Very often it seems that

those transverse valleys are situated in the place off ormer folded ridges. By this we can see that there was a structural predisposition. These features are to be seen more clearly in the case of the longitudinal valleys. Some of them are in a mature stage and very well developped (Galatura, Yatipauwa Ela); they are excavated in the synclines. The others have attacked the anticlines and worn away the soft material. Very often the process of clearing is just beginning (Bambaragalla) or it has gone very far (Walaal Dola).

Further to the West we come to a long trench (IV), six miles in breadth; thes one has an irregular hilly topography, of complicated direction, also the height is not great. We will call this longitudinal lowland the trench of Ratnapura. It streches out from the river Ellawala on the West to the Kuru Ganga to the East, reaching the height of the height of the Kandalla Kanda (849') and Mulliduru Kanda (1297'). Many swamps and ponts as well as the cut-offfs on the bottom of that trench of Ratnapura show the very old stage of development of this region; the landscape is for the most part covered with large forests. This longitudinal trench is used by the railway, which goes northward to the Eswatta.

We come now directly to the Central Massiv of Ceylon. It begins in the above mentioned profile with the group of Adamspeak (7360', whose slopes our profile cut at 6200'). From the Western part it is bordered by a region of a transitory character from 500' to 4000' high (V). It forms the hollow of the subsequent valley of Maskeliya Oya or Kuru Ganga valley. It facilitates the access of the Adamspeak from Ratnapura. The mountain-ranges become regularly higher in the Eastern direction: Bellugala (2083'), Batiya Galla (3122'), then Kunadiya Parawita (5186'), at the end Adamspeak (7360') itself.

Adamspeak forms the culminating point in a landscape (VI) of mature stage of morphological developement although situated at a great altitude. It shows mild slopes and broad valley-plains. They all break down abruptly in a Western direction along the eminent fracture, which borders the Central Massiv. But to the East, they incline slowly from a height of 6000' and 7000' to 5000'. Here follows some undercut of slopes at the altitude from 5000' to 3800'; the old landscape of Adamspeak passes over in a curious stretch of land dissected by valleys (VII). It is bor-

dered in the East by a well developped plateau, analogous to the Adamspeak-region and called Horton Plains (VIII). This striking region of heighland-valleys is drained in the NW-direction by the river-systems of Kelulgomu Oya and Namu Oya with the tributary Agra Oya. There we can distinguish a thick and young net of valleys in which the tributaries have very complicated courses.

The existence of this whole net of rivers betrays that it was formed on the old worn-down-plain; it is like an upland-terrace, but well dissected. As the remnents of the upland-terrace we can accept all the waterdivides between the valleys. Thus reconstructed the upland would form a soft rolling, but homogeneous plain, which can be easily reproduced at an altitude of 3800' to 4200' Therefore, the dissection mounts the depth of 2000', and above there rises an old landscape, such as we have met before on the Adamspeak, and shall still recognise in the Horton Plains.

Very softly there rises above that monotonous upland the watershed of Maskeliya Oya and of Humbatota Oya, called the ridge of Mahanella with a height of 5060'. The same is the case with the waterdivide of the above mentioned river and the Agra Oya, which flows from a plateau 5200' heigh, called the ridge of Alahapelahena 6203'. These watershed-ranges separate some valleys, four miles broad, at whose bottom we find often some rivers to-gether, flowing parallel to each other, in the same valley. They are witnesses of an old systematic water-drainage. It begins on the mighty declivious edge, which cuts the Central Massiv from the south; then it is directed to the North, or rather Northwest.

Turning to the East length on the profile we reach on the Western part of Kirigalpota the striking Horton Plains (VIII). We can wander for hours directly to the East on a soft undulated highland, which deserves the name of plain, although its absolute elevation in general amounts to 7000'. This highland is crossed by very old, broad and shallow valleys, in one of which Nuwara Elliya is situated. Here and there we find prominent isolated hillocks of mild slope from 500' to 800' high. They give the impression of monadnocks, f. i. the Kirigalpota (7857') and Kudahagalla (7610'). These monadnocks and some others of not so great importance have a characteristically decided topdgraphical distribution from NW to SE.

The landscape of the Horton Plains, at a great altitude but morphologically in a mature stage of developement, descends abruptly near the Mount Ohiya (7077'): it becomes a highland well dissected by shallow valleys (IX), being analogous to the upland of Maskeliya and the Agra. In the South it passes into the rocky and asymmetrical range, which divides the basin of Mahaweli Ganga from that of Kuda Oya. Along the range there runs the railway from Ohiya to Haputale.

This range towards the South ends by an escarpement 4500' deep. To the North it, on the contrary, traverses imperceptibly into the many valleys of Mahatotila Oya system. Upon this highland, well dissected by mature valleys, there are the military parade-grounds at a height of 4100' to 4300' (Pepper Box Hill, 4333'). There also is situated the well known city of Bandarawela at a height of 4150'.

Towards the East this type of landscape is bordered by the range of Balagalla-Elakanda (6375'), ending in the East with the edge well dissected by many valleys. In the North of Koslanda-Rosebury we observe many mountain-ranges from 4000' to 5000' heigh, cut by longitudinal valleys trending NNE to SSW. It is a declination from the dominant direction in the West of Ceylon, so that we have the impression, that it is caused by the geological structure. The region was submitted to a fault and then diversified by erosion.

The totality of the landscape to the East becomes an alluvial plain that of Kosgalla Oya, Parapa Oya and Kuda Oya; the same plain we have between Wellawaya and Buttala. It forms a beautiful region of terraces. Single rocks are pominent trending lengthwise in N-S-direction (so Marutukanda, 2008', Miminnahela 2118' and Magillekanda 1219'). The dry water — gaps show that there were great dislocations of the river — channels as well as the deep clefts caused by tectonic process (NE Buttala).

This short description' of only one morphological profile across the mountains of Central Ceylon allows us to draw an important conclusion: the mountains of Ceylon are of many types; they are composed of various morphological parts, whose variety are in vivid contrast with the monotony of the geolocical stucture of Ceylon, as it is known at the present.

There is no geological Survey of the country. In the year

1902 a Mineralogical Survey began its investigations; it has proved, that the mountains of Ceylon are composed in greater part of old crystailinic rocks, especially of gneis and some crystal limestone; the later are perhaps deep sea-deposits, distinguished by great riches of minerals. There are also some parts of younger sediments submitted to such a degree of metamorphism, that they seem inseparably joined with the crystallinic rocks. These are gneisses or granulites of the well known Indian-Charnochit-serie in all their variations from entirely acid to strongly basic type.

For the morphologist it is quite certain, that the variety of the types of landscapes in Ceylon is not based upon petrographical conditions; we must trace it only to tectonic causes. This is the only way to show all the structural processes by morphological analysis: the uplifts, fractures, faults and folds. Purely tectonic investigation is rendered more difficult in a country by petrographical monotony.

When studying the above mentioned profile, we cannot refrain from forming the following hypothesis for the morphological exploration of Ceylon.

1) The Central Massiv of Ceylon was formed by young uplifts followed in two series. These upheavals were unequal in differents parts of the country, stronger in the South and the West, than in the North and in the East.

2) This process of uplifts has in consequence brought forth a series of other results; the folding of these layers, which were pressed by the uplift and glided down; the fracture and sinking in of the border-parts; the later have formed some basins and fault-steps.

We will now explain this hypothesis in detail. Of course it can be definitely established only by precise field-work. First, we must explore the age of the uplifts. It is impossible to compare these upheavals very important for the analysis of the morphology with the old system of folds and pressures pointed out by the geologists. The tectonic structure of the rocks and their character of metamorphism were created already in the paleozoic era. Evidently the morphological uplifts belong to much more late, perhaps to cenozoic movements. This is proved by the fact, that at present the river-systems are not in accord with the morphological conditions.

That the latter were caused by the recent upheavals, is visible

in the great struggle of the rivers to shift their divides. We shall speak further about this phenomenon. An especially interesting and convincing example is provided by the valleys of Hirikatu and Belihul, which flow from the Horton Plains towards the South. Both valleys are an important result of the revival-process. There exist deep gorges whose profiles have the shape of the letter V; the valley-floor is quite narrow, unaccessible and steep-walled almost without terraces.

There is a strong discordance between this region and the Horton-Plains, being gently undulated upland. The quite straight ravine of the Hirikatu valley is carved to a depth of 4000'; it has an important valley-outlet. The steep cliff-walls are some thousand feet high, so that they are called „Word's End". The forms of the Hirikatu-valley are very undeveloped, being cut into the resistible crystallinic rocks. By comparing the quality of these rocks with the forms of the valley, the late date of the revival-process is quite evident, as well as the uplift,of the Central Massiv.

What is still more convincing is the investigation of the Western Belihul-valley. Near the valley-outlet, it is more wild and younger than the Hirikatu-valley. In mid-course it forms a prominent fracture of the slope (Bakers Fall). Through this fracture we can ascend the upland of Horton Plains, where there is situated the old, meandered and shallow part of the upper valley (valley-head). In other words: the revival-process of the Hirikatu-valley has produced only very young morphological forms; the whole valley has been attacked by a change; this change was caused by the deepening of the lower part of the river through retrogressive erosion; but the valley-head although it is eight miles long was not touched by the above mentioned revivel. Bakers Fall divide the six miles' upper course of the river (of a descent 50' to a mile) from the lower part (two miles long and with a descent 2000' to a mile). That is an argument in favour of the assumption that only one quarter of the valley-system was attacked by the revival-process. That can be a proof for a very young date of the uplift. We can understand the details of these mountain-forming movements only from the exact characteristic of the types of particular landscapes. We assume that the former surface of Ceylon is preserved until now in that morphologically old upland of the Horton Plains and of Adamspeak. It is particularly well developed between the Horton Plains and Pedrotallagalla.

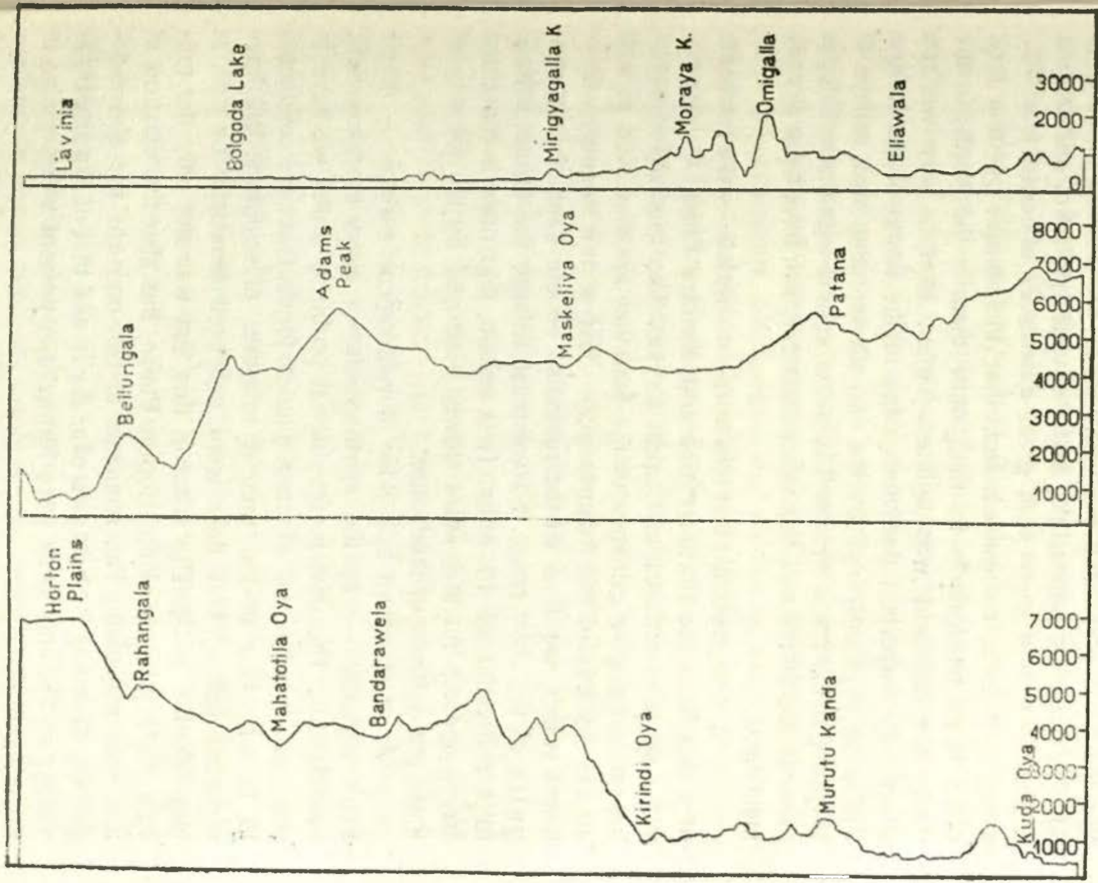
Here it forms a strip of high land, four miles broad, in the North circa 6100' to 6300', in the South nearly 7100' high; the surface shows some domed summits and valleys only 100' to 200' deep. The bottom of these shallow valleys is floored with great alluvial deposits; they are accumulated on the deeper parts through the meandered rivers and landslides, these are: brown loam, pipe clay, gravel very often compact to a depth of 40'. They are covered everywhere by scanty grass (steppes), here and there are visible lakes and swamps; upon the dome-like elevations there grows thick jungle. In the quite diversified old river-system of Dambagasta Oya between Ambawela and Pattipola we find swamps at the height of 6100'. It is not to be wondered at that the name „plains" occurs very often as Horton Plains, Elkplain Moonplain and so on. From the upland there rise domes from 1000' to 2000' in height, softly arched. These are: Pedrotallagalla 8298', Kondagalla 6993', Hakgola 7126', Tolupola 7741', Kirigalpola 7857', Kudahagala 7610'. They were mentioned before as monadnocks. They can be partly accepted as remnants of old watersheds (Fernling). The Conical Hill, 7114', and Ohiya, 7077', coincide completely with the upland itself. In the topographical distribution of the morphological features we can easily establish the preponderance of the NW trend with some feeble declination towards NE; its tectonic predisposition is quite certain.

In the North the upland contains not only the „plains" near Nuwara Elliya, 6189', with the Gregory Lake, but it streches farther towards NE to the Kandapola. Here begins the declivity to the North on the asymmetrical valley-pass, which can be compared with the Maloja of the Alps. The valley-pass of Ramboda towards the NW has a similarly asymetrical form.

This highland descends with bold escarpements on all sides; the rivers cut them forming waterfalls (Elkinfall). But from this upland there runs to the North a prominent mountain-system arching softly in a ramification to the West. It is further broken by the Mahaweliganga.

As to the whole situation the Central Highland was formed upon not very great altitude above the sealevel. We shall not be wrong if we accept for the total of uplift, by which the upland has risen to the present situation, a minimum of 5000' to 6000'.

There were, as we can see, some sporadical uplifts; they



Profil through Central Ceylon along the 6° N.

have placed the Central Upland obliquely. We have mentioned above that the Northern part rises gradually from 6100' to 6300'; the Southern part of the upland is at the altitude of 7000' to 7100'. It is quite impossible, that the valley-plains of such an old landscape should show such great differences of height from 700' to 900'. It is a recognised fact, that the oblique position took place more particularly in the South than in the North; in the South the highland was uplifted higher. In this way we can explain the important declivious edge in the South of the Horton Plains. It is deeply cut by the two above mentioned valleys of Hirikatu, Belihul and others. The same case is with the soft slopes towards the North and the valley-passes, which have been already mentioned.

It is very probable that this worn-down-plain — the remnants of which form the Horton Plains and Nuwara Elliya — once covered greater surfaces of Central Ceylon. The very old morphological forms give evidence of the fact; they are preserved as well on the SE side of the Adamspeak — just as the swampy valley-heads which we find as the remnants on the East of Doturugalla of the chief range. So we must enlarge the former surface to the breadth of 15 miles. It is certain, that once it contained larger spaces, but they were slowly destroyed by the forming of these many types of landscape.

We must accept this older morphological surface — if we think logically — as the starting-point of every morphogenetic investigation. The next morphological problem, which we have to solve are the changes of morphological forms, that have conducted to te formation of the present treasures of sculpture. We have accepted before, that they were produced especially by one, at least double uplift. The effect of this fact was not only the present high positon of the Horton Plains, but also the creation of a deeper peneplain. The remnants of this one are the above-described plains of Bandarawela, Agra and that of Maskeliya-valley; at the end there were formed the present valley-plains in the interior of Ceylon.

The plateau of Bandarawela contains pretty large and compact space between the Western border edge of Namunakuli and the Eastern slope of Hakgala; it reaches in the West to the Wilson Bungalow, in the North to the Duhinda Falls, in the South across the Bandarawela and Diyatalawa.

It forms a type of erosion-mountains; its thick net of valleys shows 1500' of depth, but the summits coincide in one wunderful, diversified, softly undulated plain. The plateau descends abruptly to the North in the neighbourhoud of Duhinda Falls, North of Badulla. There the Badulla Oya falls down in a wild, narrow gorge from 2200' to 1400' slope. The road from Badulla towards the North avoids this pathless ravine and descents on the slope of the plateau in many serpentines. The retrogressive erosion — a result of the second uplift of the mountain — began the carving from the plain and has not yet advanced across Duhinda Falls. On the contrary the first uplift caused not only the mature valleys, but also the fine peneplain of Bandarawela-Badulla.

To analogous conclusions we are led by the observations of the Hatton trunk-plain. That name we shall give to the upland between the Horton Plain and Adamspeak. It contains quite a large space between. St. Andrews in the SW, Rozelle in NW, Naru Oya in NE and Totupola in SE. It is surrounded by a chain of mountains from 5000' to 7000' high; it represents a plateau of an average height of 4000', which, like that of Bandarawela is dissected by thick, but shallow valleys.

The head-rivers of this region flow similarly towards NW; so the Maskeliya Oya, Kehelgomu Ganga, Mahaweli Ganga, Nanu Oya and its great tributary Agra Oya. On the contrary the tributaries generally are directed to the NE; they advance along the line of structure and have the features of short transversal valleys. The highland very often had a form of a broad valley-terrace; it seems, that this terrace has plained all the ridges, wich separate the neighbouring valleys. A good example from Nanu Oya. Drawing a cross-profile through that valley near Talawele we see: a narrow valley-floor deep only from 300' to 400' and 1 to 2 miles in breadth; on both sides there are remnants of high terraces, which end sharply towards the mountains in the South (Kalagela 5757') and in the North (Great Western 7269').

These broad remnants of terraces reconstructed form a peneplain. It proves, that the erosion-cycle caused by the first uplift of Central Ceylon was accomplished up to the formation of a normal worn-down-plain. This process was produced by the second uplift of the mountains. The first upheaval was capable of producing not only the mature valleys, but also the wonderful trunk-plain of Bandarawela-Badulla.

It was a different matter with the revival-process produced by the second uplift. As in the plateau of Bandarawela, the retrogressive erosion proceeding only from the foot of the mountains has reached the edge of the Horton Plains. The mature valley-floors of that plateau descend abruptly with many fractures towards the plain. These fractures are ornamented by waterfalls and cascades. A fine example of such landscape is formed by the surroundings of Talawakele. This place is situated at a height of 4100' upon a broad valley-floor; the railway crosses this one without difficulty. But immidiately underneath there is an inaccessible gorge steep-walled (the walls 700' high).

The situation of the Ramboda Falls in the North has the same morphological significance. At the Mahaweliganga the revival reaches nearly to the Watawala; here the river at a short course falls from 3200' to 2800'. Further down it has also a greater descent than in the mature course near the source. The railway must make serpentines round the source-region of the Massenawalla Ganga. At the Kebelgamuganga the steps of Watawele correspond with the serie of the Aberdeen Falls (217' heigh).

Once accepting the twofold uplift of Central Ceylon as a self evident fact, we have to explore the size, the time and the localisation of these uplifts. As to the size, we can form conclusions from the differences of the altitude of the old upheaved niveaus anh the young ones, which are affected in their development by the uplift. A precise understanding of these differences can be achieved by a detailed exploration of a chart, which reconstructed the levellisation of Central Ceylon.

From the isanabases, drawn on such one chart, we can recognise the topographical distribution of the intensity of the uplift. But I did not have opportunity to make such an exploration, which can be done only by field-work. For this reason we will give only a general idea. We have before accepted that the whole uplift of the mass of Horton-Plains amounts from 5000' to 6000'; it was stronger in the South than in the North near Nuwara Eliya. This uplift was divided into two series of upheavels: first, there was upturned $^1/_3$ of the whole mass, then the rest of $^2/_3$. We base our opinion on the striking fact that the trunk-plain of Hatton and Bandarawela coincides at the height of 4000' to 4500'. It is nearly 2000' lower, than the altitude of the worn-down-plain of Horton.

Therefore the first uplift amounts to nearly 2000'; the rest from 3000' to 4000 belongs to the second upheavel. We must remark, that the obliquity of the Horton Plains-level was produced by the first one. During the formation of the Hatton-Bandarawela-niveau this obliquity was an accomplished fact.

These conclusions facilitate quick orientation; there are grounds for supposing, that a chart of isanabases of the Central Ceylon Massiv would be the base of many interesting conclusions.

More difficult is the question about the t i m e of these uplifts. Here we have no settled facts; only a detailed geological exploration may give us one, but not the investigations of the old crystallinic rocks, rather the researches of the recent and the newest deposits, of the coastal terraces of different age and those of the valley-floors, which are connected with the former and so on. But such and exploration has not yet beem initiated and it would be an error anticipate it by guessing whithout a foundation not sufficiantly proved.

We can say only this, that the continent-forming movements of the Earth, which are morphologically very important, are usually joined more closely to the fractures than to the folds. Probably such movements have not influenced the formation of the mountains, whose effect was the folding of the gneiss and the metamorphism of the old sediments.

The second fact is that the last epeirogenetic movement has not yet conducted to a morphological equilibrium; it allows us to form a conclusion, that this movement was of very recent date. These mighty narrow passes, graduated slopes and waterfalls are to be seen especialy in those mountains which have been set out in the diluvial time. The older epeirogenetic movement caused the formation of a trunk-plain. In other mountains this fact is associated with recent and old tertiary period; this means that it belongs to the mountain-forming movement of the cretaceous period.

Therefore, we shall accept — but quite without obligation — that the older movement of Central Ceylon took place in the tertiary period, the recent one in the quaternary period. The latter had a greater intensity. This is evident from the] fact that the effects of the revival are greater, and from the point of view of landscape they are more beautiful and younger. On account of this we can conclude from a morphological point of view, that

for Ceylon the recent period was really unquiet. This is confirmed by the observations of the Mineralogical Survey (Report for 1905, 1908); there it has been established, that after the formation of the coastal-sands with the aid of the wind, waves and currents there took place some little uplift. This renders the compactness of the sands possible; they became recent sandstones and were submitted to a process of erosion. Then there follows a downthrow which renders possible the transgression of the sea, the formation of lagoons and piling up of sea-shells upon the region nowadays qnite dry. This dry continent was formed by a new uplift, which has continued up to the present time. The orogenetic oscillations in which Ceylon took part in later times, coincide with analogous movements in India. There Oldham (Geology of India, 2-nd ed. p. 406—409) found young coastal conglomerates upheaved, as well as drowned forests (Bombay, Tinniwelli) and the alluvial deposits situated up to the present under sea-level (Madras 50', Pondicherry 550'). These facts confirm the opinion of the modern dow-throw movement.

Finally the supposition about the young movement of the earth-crust in Ceylon is strengthened by the frequency of hot springs, which are to be found over the whole country, although they have not beem examined (for instance near Marangola, Maha Oya, Kapurala, Mahapelusse, almost 110—130 degree Fahr.). There are also young volcanic phenomena, but they were investigated only in few places (Report for 1902, 1907). And so the question of the young movement of the crust in Ceylon attrack leads to a series of succesive geological and morphological explorations.

With the question about the intensity of the epeirogenic movement is closely joined the question about their territorial extent. Here also we must restrict ourselves to some interesting observations of the relief; further investigation of the question, must be left to fieldwork. When we observe especially the Central Massiv, we must establish firstly: that there are triple directions caused by the structure and important for the morphology of the above mentioned Massiv. These are: the NW, the NE and the E-trend. The first we cannot denote as the revival of the old folds trend of the former mountains. The finest examples of them are: the formation of the valleys upon the Hatton-plateau; then the ranges, which begin at the Horton Plains trending to the NW; finally

the preponderous longitutinal valley of Ceylon — it is the 14 miles long, precisely straight Logat Oya in the East. The anticline of the Namunakalunda near Badulla strickes parallelly with the above mentioned valley.

Towards the NE there trend only secondary ridges and valleys. This direction is sharpely expressed in the morphology and coincides surely with a system of clefts. This one crosses the old fold-system at a perpendicular angle. The geologists of Ceylon have also established the frequent appearance of the cleft-direction (Report for 1907, 1908); we must join our opinion to their observations on the morphological importance of that cleft-course. There is a new observation that we must take into consideration: the existence of a structural direction E — W, which is to be observed also in the morphological sculpture of the mountains of Ceylon. It is expressed not only in the direction of the valley-net (see the middle course of the Mahaweli Ganga, in some ridges of the mountain (Pedrotallagalla 8292', Ragalla 5917', Narangalla 5011'), which are in the North of the (Bandarawella-levelplain), but especially in that powerful morphological detail of Central Massiv which is — its Southern escarpement.

It extends nearly 50 miles trending from East to the West; it is high from 4000' to 5000'; the abrupt slope shows all the features of a tectonic fracture and of a graduated step. It is diversified by erosion. The straight concordant direction of many water- and wind-gapes of the ridge-line is quite comprehensible. We can explain the stricking altitude and the great extension of this landstep probably by a topographical coincidence with the lines of fractures of both uplifts. On account of this the morphological effect was strengthened. It is quite comprehensible that to these different processes of the Central Massiv there are corresponding reactions in the surrounding: as such we consider 1) the folding in the SW, 2) the fracture-regions in the North, 3) the graduated faults in the South-East.

About the latter it is impossible for me to say any more. They contain the region North from Koslanda-Rosebury with a range trending NNE; it becomes continually lower to the East; at the end it passes into the region of sandy Jura between Wellawaya and Buttala. It gives the impression, that the East edge of Central Massiv was submitted to a process of torsion and tea-

ring assunder; it may be analogous to the mighty graduated fractures in the Eastern coast of Asia.

In the West of the Central Massiv there is nothing of this kind to be observed. Under the influence of the uplift of Central Massiv there took place rather a pressure and a folding process in the neighbourhoud. The relief which is examinated in our study, at the first glance gives the sense of the beautiful morphological effect of the folding-arches; they press together to the South and the West round the Central Massiv. Arround the foot of the Massiv is encircled, as by a wreath, by numerous folds, largely like well-modelled mountain-ranges; there are many longitudinal valleys in a succession of the synclines and anticlines. In the profile, we recognise these fold-arches from 10 to 15 miles broad, in that place, where they are best developed. We shall first follow them from the region of Adamspeak towards SE and then to North.

There exists, in the region of Morawaka an enlarging of the folds-sphere; the relief becomes more complicated. The folds run here round a part of plateau. There is on a great altitude (800' to 1000') a level plain with lakes and swamps. They are the proof of a mature stage of that plateau with little slope. The greater part of these swampy lakes is situated near Waturawa, it is surrounded by a bold escarpement in a form of culverin. This region can be the subject of a very interesting morphological detail-study. It shows fine valley-divides, epigenese, threatening captures of rivers. In this region the intensity of the folding process has diminished. In the Eastern part there took place the phenomenon of torsion; as the effect of this we can accept the important edge 2500' high, which runs from Hingurakanda across Rammalekanda to the Deniya Kanda and Gombadala. Towards North, or rather NW all the vaulted ranges are submitted to an aproach to the Central Massiv. Between them and the Southern slope of the Central Massiv there enters the trench of Ratnapura. In the North there is not a trace of this trench between the folded mountains and the Massiv. The cleft of Ratnapura enlarges towards SE; in the East from Opanaka and Rakwana, in the region of Walama Ganga singular rocks rise from the broad-floor of that crushed zone. On account of this the relief becomes more and more complicated. Towards the North the trench of Ratnapura disappears already in the region of Ari-

savella; at that place the Jurassic folded region comes directly into contact with the Central Massiv.

On an other side the folded ranges disperse fanshapedly towards NW; there is formed a typical ramification. The particular arches move farther and farther asunder; they are divided by broad alluvial plains; at the end they rise from the valley-floor as narrow isolated small rocks. The zone of folded mountains becomes towards North filled up with sand; finally it is drowned completely under this covering. Especially interesting, from that point of view, is the region, situated NW from Wenda and the well known surrounding of Kurunegalla. There appear from alluvial deposits some isolated ranges and run arching to the NW. The most beautiful of them are the Humpola Kanda 2703'; the splendid sickle-shaped Jakdessagalla 1721' and the Kandalawa with the Takehenagama near Batagola Tank.

The dying sway of the folded zone in the North betrays, that we are near a region, in which the continent-forming movements have a negative tendency. This opinion is still strengthened by the existence of a region of tectonic basins; they can be easily established as the compensation-phenomena to the uplifts of the Central Massiv.

The finest of these fault-regions is the triangular basin of Tumpalata: a large plain from 4 to 5 miles broad is crossed towards the North by the straight Maha Oya river, but in the above mentioned direction it becomes wedge-shaped. The longitudinal axis of this fracture-region runs to the NNW and is nearly 10 miles long. On three sides this region is rimmed by sharp edges. The highest of them is the Southern scarp, where the Sandy Box Massiv ends abruptly in a mighty step strongly, however dissected by rivers. More complicated is the Eastern fault-scarp, where there are mixed two graduated steps; the direction of both declines one from the other about 20 degrees. They are 1) the 5 miles long and 1500' high land-step of Kekunagalla (2300') and of Hingurugalla (2194') and the step nearly 7 to 8 miles long, which runs from Belungawa near Kadubannawa to the Kadigamuwa (1829').

The Western edge also sharply represented, trends from Arama in the South towards the Udagama near Rambukkana in the North. It is cut by three gates, well formed, and one quite undeveloped. The most stricking is the one of the Hat-

gampola and Debetgama (842'): it rises only 50' above the level of the crushed zone. It is dug between Batagela (2610') and Ramesarakapella (3667'). In a state of preparation there is the gate of Galatara. The two remaining-gates near Delimawuda and Digana are used by the rivers especially the last by the Maha Oya itself. Above the plain of this crushed zone there rise small isolated island-rocks. They are perhaps the remnants of the faultscarp or of volcanoes (Dewuragalla, 1089', Kalaotuwagalla, 1602'). It is very likely, that there can be demonstrated other analogous crushed zones, although not so well developed. Such is the case, for instance, of the plateau which extends North from Kandy Matala at an altitude from 1800' to 1000'. It forms a part of highland which divides the plain of Mahaweliganga in the East from that of Kimbulwana Oya in the West. It is certainly on both sides surrounded by a faultscarp. Such crushed edges accompany f. i. the railroad Watagama-Matala (SW-NE) and the high-road Kandy-Wenda and so on.

Upon the foundation of that quite general observation, supported by the cartographical material, the morphological development of the mountains of Central Ceylon presents itself extremely manifold and complicated. On account of this the river-net of Ceylon must be composed in its developement of heterogeneous parts. There is a rule — old age must always make noon for the youth — we can hope that the particular landscape, which correspond to the various state of developement, they do not harmonize, but are in vivid contradiction. It is also very easy to prove that there are to be found in the same valley-system vivid contrasts of landscapes: here the forms of erosion and there of accumulation. The strife to capture the neighbouring river-systems is fought inexorably and not with equal forces. The effect of that is constant transformation in the river-net of Ceylon. We will prove this general suppositions by the observation of the principal stream of Ceylon, the Mahaweli Ganga.

The general situation of the river-net of Mahaweli Ganga in itself must awake our curiosity. The main river finds it source in the SW-corner of the Central Massiv; then it flows parallel to Western edge; but afterwards it does not pay attention to the possibility of running off towards the West and it forces its way through the high mountains to the East. In this extraordinary for-

mation of the river-net we can recognize only the former conditions of it, which was formed under circumstances quite different from what they are at present. Either the mountains — cut by the Mahaweli Ganga in the Eastern direction — are younger than the foundation of the river-net — in that case this one is antecedent — ore there were once in the West of the island higher mountain-groups, from which has flowed the Mahaweli Ganga, forming part of a consequent river-net, directed to the East. In the latter combination we can adopt the old hypothesis — very often discussed, but also denied — of the connexion of Ceylon with Southern India.

At the present we have no more materials to prove it and we have no possibility to dicuss both probabilities explainting this phenomenan. We can only say this, that the Mahaweli Ganga in its whole course within the mountains represents an anomaly; being such, it can be very easily threatened by the neighbouring rivers not without success.

At a more advanced period there is conducted this process of imminent capture at the Ginigathena; a water shed, 2200' in height, rises above the valley-floor of the Mahaweli scarcelly 200'. At the same time it is only 500' distant from the river. In the neighbourhood the Kehelgomu has attained a deeper level at only 700' above sea-level. It is a classical example of imminent capture. It will be sufficient, to mention, that the tributaries of the Kehelgomu, which flows with a great descent, carve their channels 200' in depth in order to direct the whole upper course of the Mahaweli Ganga to the Kehelgomu; near the Ginigathema there will be formed a characteristic capture-knee, a valley-divide and an „overfit" valley.

In its further course the Mahaweli is forced by the Massiv of Sentry Box to make a bend towards the North and Northeast. Some parts of the mid-course of the Mahaweli Ganga may be captured in the future as well by the great rivers, which flow towards the West (Ritigaha Oya and especially We Oya) as by the tributaries in the neighbouring, already known, crushed basin of this Tumpalata (Manay Oya). The divide between the Kuda Oya and Mahaweliganga is 2400' high. Near the Gampola the distance of this watershed from the Mahaweli Ganga reaches three miles (1600', nearly 300' descent to a mile); and it is distant only one mile from the Kuda Oya (1600' descent to a mile).

Between the Gampola and the Kandy the Western coast of the Mahaweli is accompanied by curious highlands; in the region between the Gampola and Peradenyja the reach the altitude from 2000' to 2100'. Then towards the Kandy they become only 1800' high. The highlands are richly dissected by a diversified hydrography; they are carved by deep gorges. We can establish them as the resound of the near lines of fractures. But the most striking feature in the hydrogrophy are the double-valleys. The first example is to be found between Gambela and Peradenyja: the railway and the highroad go through the Western dry valley, the river uses the Eastern pathless valley. Near the Peradenyja this fact changes on account of the meandering of the Mahaweli. Downwards the river flows through the Western valley and the railway is built along the Eastern dry valley towards Kandy. We can trace this dry valley below the sharp knee of the Mahaweli Ganga at Kandy; at the beginning of this valley there lies the curious valley-lake of Kandy.

This knee of Mahaweli Ganga near Kandy is worthy of consideration for two reasons. When observing the ranges which precede in the North the Nantana Mountains we make the following conclusion: there is a sphere of strong tearing and fault-building. Near Kandy the middle part of that range bursts and makes a bend to the North, as it happens with cords too strongly strained. Therefore there is formed a breach which is used by the railway from Kandy to the North. And yet the Mahaweli Ganga winds softly round the crushed ridges like a cable joining the parts of a mountain-system broken to pieces, it does not flow Northward, also just here there exist no difficulties for the swift running off towards the plain.

There extends a triangular plateau 1800' high; it is blocked up by the fault-lines Kandy-Wenda and Wattegama-Matale. North from the Matale it descends from 1000' to 800' downward. And the Mahaweli Ganga instead of running to the North, forces its way to the East through a mighty, 3000' high mountain-range. This permits us to form the conclusion that the valley of the Mahaweli Ganga is antecedent.

Really it enters into this mountain-system already at the Gangepityja nearly 10 miles East from Kandy; there begins the greatest transversal valley of Ceylon (18 miles long). A series of parallel ranges is cut through; another series of small basins

is formed in the place of crossing of this transversal valley by the Mahaweli Ganga and the secondary longitudinal valleys of the mountains.

We find meanders only at two places; we may rather suppose, that they are formed by slipping off then that they represent a type of antecedent entrenched meanders. We remark the first meander immidiately at the beginning of the transversal valley, below the mouth of the Mana Oya; there is the Kandagola-ridge (2208') surrounded by a long 1100' deep serpentine of a river.

In the developement of the transversal valley we can distinguish two periods. Everywhere in the adjoining valleys we find the symptoms of two cycles of morphological developement. This means: a wealth of mature forms in the upper course, and the evolution of young forms in the lower part of the rivers. The developement has not yet attained its aim of destroying the former sculpture. And so the valley of Maha Oya is quite mature to the place, where the railway crosses the river; below it is quite young. A particularly good example is formed by the small valley of Wendaruwe, which has its mouth North from the Kalapatuewela. The upper course is a gentle amphitheatre; the lower course is a young gorge. The breaking of the descent lies at an altitude of nearly 1200'.

The lowest part of this transversal valley is especially wild. It means the last 5 miles of the course of the Mahaweli Ganga within the mountains. There are ridges sharpely cut and directed across the river to the North; the transversal gorge is cut 2500' in depth between the Weddandamana (2811') and Kandenigala (2598'). After the confluence of the Uma Oya in the South (a longitudinal valley) and the Maha Oya in the North there takes place a second breach between Wattegalla (1753') and Nagobanena (2340'). After the last one between Kahagalla (1001') and Watagoda (798'), Mahaweli Ganga flows out into the plain. There, receiving its two great Eastern tributaries, the Badulla Oya and Loygal Oya, the main-river immidiately directs itself to the North; it does so perhaps under the influence of the above mentioned tributaries. At the end the Mahaweli Ganga reaches the sea at the Northeastern shore of Ceylon.

Conclusions.

With these suppositions we will close the results of the morphological studies on the relief of the Survey-Departament. Thousands of observations might be made upon this relief; they can be more or less clearly included into the above-drawn sketch of the mophogenese of Central Ceylon. We will no longer burden our short sketch, because the whole construction of the working-hypothesis could only be strengthened by investigation in the field. It remains only to collect the main-ideas of this outline and on their basis to establish the working-hypothesis for future investigations in the field.

1) The landscape of Central Ceylon is very diversified; it is caused by the twofold young uplifts and by one oblique position connected with them, by stow-folding and tectonic basins as phenomena of tearing.

2) The former valley-systems endeaveour to adapt themselves in more or less full mode to these new conditions.

3) The first of these uplifts upheaved the old worn-down plain, the Horton Plains-niveau nearly to the height of 2000' and by the same movement this plain has been obliquely placed.

4) The revival process of the valleys, caused by this fact, has destroyed the greater part of this niveau. But it has led to the creation of a new worn-down-plain — the Bandarawela-Hatton-niveau. — The former is marked off sharpely from the latter by a step and waterfalls.

5) Of greater importance for the morphology was the second uplift which has caused the revival process of the Bandarawela-Hatton-niveau. By this one the Central Ceylon has at the same time been obliquely placed in the Northern and Eastern direction. This fact rendered it possible for the former valley-net to preserve its old directions.

6) This second uplift was stronger than the first one; through the stowing it has produced on the West side a folded mountain-system. In the South it passes into phenomena of tearing and in the North into a ramification (virgation) of ranges.

7) There were joined with them young formation of crushed basins and graduated faults; they accompany Central Ceylon round its periphery.

8) By this processes the former equilibrium between the

singular river-basins was remowed; this fact led to the strife for shifting the devides, which is carried on partly with results.

9) The important revival process caused through the uplift brought forth a great mass of accumulated deposits; on the periphery the mountains are entirely or partly filled up with them; and further on, there are formed, with aid of the sea, the broad alluvial plains, which at the present surrounded the Central Mountains like a wreath on all sides.

10) At present we cannot establish the age of all these processes.

11) The influence of the petrographical and tectonical predisposition must also be minutely examinated.

12) The youth of all these procesess is quite probable, because of volcanic phenomena, warm springs and recent dislocation of the sea-shore.

13) The morphological investigation of Ceylon has special importance, because in its evolution seems to represent a cross between the African fractured and the Eeastern-Asiatic torn-typ of landscape.

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